UNITED STATES PATENT APPLICATION FOR

JOINT ESTIMATION OF BIDDERS' RISK ATTITUDES AND PRIVATE INFORMATION

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5   JOINT ESTIMATION OF BIDDERS' RISK ATTITUDES
AND PRIVATE INFORMATION

Field of the Invention

The present invention pertains to the field of auction designs and

10   auction analysis. Specifically, this invention relates to a method for

determining both the risk attitudes and the joint distribution of private

information of bidders.

Background Art

15   In an auction, a variety of decisions must typically be made by each of

the participants. When the auction is run by the seller, the bidders must

decide whether or not to bid. Upon deciding to bid, they must decide how

much to bid. This decision process is conditional on information that the

bidder has available regarding the objects being auctioned, rivals, etc.

20

The seller and/or the person who runs the auction must make

decisions regarding what auction format to use and the reserve prices for

items to be auctioned. Additionally, the seller must consider entry fees,

quantity of items to be auctioned, timing and duration of the auction, lot sizes,

25   bundling of items, sequence of lots, bid increments, information disclosure

policy, etc. Standard auction formats include sealed bid first price, Dutch,

sealed bid second price(or Vickrey), English, etc.

Recently, methods have been determined for assisting the buyer and

30   the seller in making these decisions. These methods typically involve

5   analysis of prior auctions for determining the joint distribution of private
information and for determining risk attitudes.

One prior art method for analyzing auction data assumes that bidders
are risk neutral and uses observed bids from available types of auctions to

10   estimate the joint distribution of private information. However, if the
assumption of risk-neutrality is incorrect, estimated joint distribution of private
information will have no systematic relation to the true distribution and hence
cannot be reliably used as input in formulations of decision problems.

15   Another prior art method for analyzing auction data uses estimation
models that are restricted to parametric families of functions for determining
the joint distribution of private signals and for determining risk attitudes.
However, there is no theoretical or empirical basis to justify the a priori
restrictions imposed on the forms of the latent functions that are to be

20   estimated. Therefore, this method also gives unreliable results.

Thus, conventional methods for analyzing auction data do not provide
sufficiently accurate results to be of use to either the buyer or the seller in
making the necessary decisions. Therefore, buyers and sellers must use

25   personal knowledge and experience to make decisions on a personal, best-
guess basis.

Accordingly, there is a need for a method and apparatus that will assist
the buyer in making decisions relating to a particular auction. In addition,

30   there is a need for a method and apparatus that meets the above need and
that will assist the seller in making decisions relating to a particular auction.

5   Moreover, there is a need for a method and apparatus that meets the above

needs and that allows for accurately determining bidder's private information.

In addition, there is a need for a method and apparatus that meets the above

needs and that allows for accurately determining risk attitudes.

5 SUMMARY OF THE INVENTION

The present invention enables a seller/buyer conducting an auction for selling/procuring an item(s) to factor bidders' attitudes toward risk and the bidders' private information into their decisions regarding the appropriate auction procedure to conduct. As neither the bidders' attitudes toward risk nor

10 the structure of private information held by bidders is directly observable, the present invention provides a method for extracting both the risk attitudes and the private information of the bidders. This is accomplished by exploiting systematic variations in bidders' behavior under different auction rules.

15 A method and apparatus for determining private information and risk attitudes for bidders is disclosed. First, auction data from previously conducted utility-dependent auctionsand previously conducted utility-independent auctions is analyzed. In this application an auction belongs to the "utility-dependent" classification if the bidding behavior it induces depends on

20 the utility function of the bidders; otherwise it belongs to the "utility-independent" classification. Examples of utility-dependent auction formats are sealed bid first price and Dutch auctions; examples of utility-independent auction formats are sealed bid second price and English auctions. Private information for the bidders is determined using bids submitted in utility-

25 independent auctions for identical or similar items. Risk attitudes are determined for the bidders using bids from utility-dependent auctionsfor identical and similar items and using the previously determined private information.

30 When the auction data from previously conducted utility-independent auctions is not sufficient for determining private information for the bidders,

5   additional utility-independent auctions are conducted. Auction data from these additional utility-independent auctions are used along with data from previously conducted utility-independent auctions to determine private information for bidders.

10   Similarly, when the auction data from previously conducted utility-dependent auctions is not sufficient for determining risk attitudes for the bidders, additional utility-dependent auctionsare conducted. Auction data from these additional utility-dependent auctionsare used along with data from previously conducted utility-dependent auctionsto determine risk attitudes for

15   bidders.

     In one embodiment, statistical density estimation techniques are used to nonparametrically estimate the joint distribution of bidders' private information and "quantile matching" methods are used to nonparametrically

20   estimate risk attitudes for bidders.

     Output is generated either in tabular form or in graphical form for indicating private information and for indicating risk attitudes. In the present embodiment, output is generated in the form of a table that indicates the joint

25   distribution of private information for the bidders and a table that indicates the risk attitudes for the bidders. Also, output can be generated in the form of a graph that indicates the joint distribution of private information for the bidders and a graph that indicates the risk attitudes for the bidders.

30   Accordingly, the method and apparatus of the present invention exploits systematic variations in bidders' behavior under different auction

5   formats. Because only bid data from utility-independent (or English) auctions

is used to identify and estimate the joint distribution of bidder information

(private information), an accurate determination of private information results.

Similarly, by using the private information along with only bids from sealed-bid

first-price auctions, an accurate determination of the latent utility-of-wealth

10   (risk attitude) function of the bidders results.

Other features and advantages of the invention will become apparent

from the following detailed description, taken in conjunction with the

accompanying drawings, illustrating by way of example the principles of the

15   invention.

5   BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and form a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention:

10   Figure 1 is a block diagram of an exemplary computer system upon which embodiments of the present invention may be practiced.

Figure 2 schematically shows an automated decision support system for designing auctions in accordance with one embodiment of the present 15   invention.

Figure 3 is a block diagram illustrating a process for obtaining auction data in accordance with one embodiment of the present invention.

20   Figure 4 is a block diagram that illustrates a method for obtaining estimates of bidders' risk attitudes and private information in accordance with one embodiment of the present invention.

Figure 5 illustrates an exemplary relationship between bidders' private 25   information or willingness to pay and the price of the item.

5   DETAILED DESCRIPTION OF THE INVENTION

Reference will now be made in detail to the preferred embodiments of

the invention, examples of which are illustrated in the accompanying

drawings. While the invention will be described in conjunction with the

preferred embodiments, it will be understood that they are not intended to limit

10   the invention to these embodiments. On the contrary, the invention is

intended to cover alternatives, modifications and equivalents, which may be

included within the spirit and scope of the invention as defined by the

appended claims. Furthermore, in the following detailed description of the

present invention, numerous specific details are set forth in order to provide a

15   thorough understanding of the present invention. However, it will be obvious

to one of ordinary skill in the art that the present invention may be practiced

without these specific details. In other instances, well-known methods,

procedures, components, and circuits have not been described in detail so as

not to unnecessarily obscure aspects of the present invention.

20

Notation and Nomenclature

Some portions of the detailed descriptions that follow are presented in

terms of procedures, logic blocks, processing, and other symbolic

representations of operations on data bits within a computer memory. These

25   descriptions and representations are the means used by those skilled in the

data processing arts to most effectively convey the substance of their work to

others skilled in the art. In the present application, a procedure, logic block,

process, or the like, is conceived to be a self-consistent sequence of steps or

instructions leading to a desired result. The steps are those requiring physical

30   manipulations of physical quantities. Usually, although not necessarily, these

quantities take the form of electrical or magnetic information capable of being

5   stored, transferred, combined, compared, and otherwise manipulated in a computer system. It has proven convenient at times, principally for reasons of common usage, to refer to these information as transactions, bits, values, elements, symbols, characters, fragments, pixels, or the like.

10   It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussions, it is appreciated that throughout the present invention, discussions utilizing terms such as

15   "analyzing," "determining," "using," "extracting," "accumulating" or the like, refer to actions and processes of a computer system or similar electronic computing device. The computer system or similar electronic computing device manipulates and transforms data represented as physical (electronic) quantities within the computer system memories, registers or other such

20   information storage, transmission or display devices. The present invention is well suited to the use of other computer systems.

Exemplary Computer System

In general, computer system 190 of Figure 1, used by an embodiment

25   of the present invention, comprises an address/data bus 100 for communicating information, one or more central processors 101 coupled with bus 100 for processing information and instructions. Central processor unit 101 may be a microprocessor or any other type of processor. The computer system 190 also includes data storage features such as a computer usable

30   volatile memory unit 102 (e.g., random access memory, static RAM, dynamic RAM, etc.) coupled with bus 100 for storing information and instructions for

5   processor(s) 101. System 190 also includes an optional signal input and

output device 108 coupled with bus 100 for enabling system 190 to interface

with other electronic devices. In one embodiment of the present invention, the

input and output device 108 is a serial communication port, but could also be

any number of well known communication standards and protocols, e.g.,

10   Universal Serial Bus (USB), Ethernet, FireWire (IEEE 1394), parallel, small

computer system interface (SCSI), infrared (IR) communication, Bluetooth

wireless communication, etc.

Optionally, computer system 190 can include a display device 105 that

15   is coupled to bus 100 for displaying graphics and/or video. It should be

appreciated that optional display device 105 may be a cathode ray tube

(CRT), flat panel liquid crystal display (LCD), field emission display (FED), or

any other display device suitable for displaying video and/or graphic images

and alphanumeric characters recognizable to a user. Furthermore, system

20   190 can include an optional alphanumeric input device 106 including

alphanumeric and function keys coupled to the bus 100 for communicating

information and command selections to the central processor(s) 101.

Additionally, the computing device 190 of Figure 1 can include an

25   optional cursor control device 107 coupled to the bus 100 for communicating

user information and command selections to the central processor(s) 101.

Cursor control device 107 allows the computer user to dynamically signal the

two-dimensional movement of a visible symbol (pointer) on a display screen

of display device 105. Many implementations of the cursor control device are

30   known in the art including a trackball, mouse, joystick or special keys on

alphanumeric input device 106 capable of signaling movement of a given

5   direction or manner of displacement. It is to be appreciated that the cursor

control 107 also may be directed and/or activated via input from the keyboard

using special keys and key sequence commands. Alternatively, the cursor

may be directed and/or activated via input from a number of specially adapted

cursor directing devices.

10   Figure 2 shows an automated decision support system 200 for

designing auctions in accordance with one embodiment of the present

invention. In one embodiment, the automated decision support system 200 is

a software system implemented in a computer system such as that illustrated

15   in Figure 1. Alternatively, hardware or firmware can implement the automated

decision support system 200.

         The automatic decision support system 200 is used to provide decision

support for auction design. This means that the automatic decision support

20   system 200 aids auction sellers, buyers, bidders, or auction houses in making

auction-related decisions. There are typically a number decisions to be made

regarding an auction. For example, in an auction run by a seller, a bidder has

to decide on how to bid and whether or not to bid in a specific auction

conditional on information the bidder has. In addition, the bidder needs to

25   decide whether or not to gather information on auctions, objects, and/or rivals.

If he decides that gathering such information is worthwhile, he must then

determine how to gather the information. The auction house for the auction

5   needs to decide fees for buyers and/or sellers. In addition, the auction house

needs to decide the options of auction formats to offer.

Similarly, in an auction run by a seller, the seller also has to decide

what the reserve price of the auctioned item should be, what is the best

10   auction format, what entry fees should be charged for participating in the

auction, what timing and duration of the auction should be, the quantity of the

item to be auctioned, what participation rules should govern the auction, and

what information rules should be imposed on the auction, etc. As is known,

these decisions affect the revenue or profit generated from the auction.

15

In order to achieve the maximum revenue or profit, the auction

designer must optimize these decisions. In accordance with one embodiment

of the present invention, this optimization is done by the automatic decision

support system 200. The automatic decision support system 200 provides

20   optimal configuration of auction design parameters and comparative

evaluation of any pair of design choices. In other words, the automatic

decision support system 200 provides automated auction analysis

optimization.

25   In accordance with one embodiment of the present invention, the

automatic decision support system 200 processes available data using

structural econometric techniques to identify the latent distribution of random

5   or unknown elements of the market structure or market environment of a particular auction. In addition, the automatic decision support system 200 provides the optimal values of any subset of the decision variables or candidates based on an evaluation criterion specified by the user of the system 200, conditional on the levels of the remaining decisions.

10

    The data available to the automatic decision support system 200 include data supplied by the user of the system 200. The data include a description of the item to be auctioned, auction decision candidates, constraints, and auction evaluation criterion. These are user inputs to the

15   automatic decision support system 200. The available data also include historical auction data and bidding model data. The historical auction data and the bidding model data are stored in the automatic decision support system 200.

20   The automatic decision support system 200 receives the user inputs of the description of the item to be auctioned, the auction decision candidates, the constraints, and the auction evaluation criterion. The automatic decision support system 200 then selects the best auction decision candidates (e.g., the best auction format is English, the reserve price is $100, the entry fee is

25    $5, and the duration is five days) among the inputted auction decision candidates based on the auction evaluation criterion and the estimated market structure of the auction.

5   The term "market structure" is a well-known term in the field of

econometrics. It means substantially the same as the term "auction

environment" (or market environment). Thus, these terms are

interchangeable. The term "market structure" indicates, in the auction context,

10   environmental factors or conditions that may affect potential bidders in the

actual bidding during the auction (or in the auction-related decision making

process). In other words, the market structure indicates the factors that may

affect a bidder in decisions related to the auction. This term also covers the

structure of private information held by bidders of the auction. The private

15   information specifies any information held privately by a bidder or potential

bidder (i.e., information not possessed by other bidders or seller). Typically, a

bidder's willingness to pay for the auctioned item is known only by the bidder

himself/herself. Another example of the market structure may be the results of

privately conducted tests obtained by individual bidders before the auctioning

20   of an item, like an oil and gas contract. In this case, the value of the auctioned

item may be the same for every bidder, but each bidder has a private

estimate of what that value may be. Another example of the market structure

is that the current capacity utilization of company bidding for a contract is

typically known by the company itself and not by rival bidders. The market

25   structure affects bidding behavior of bidders during the auction.

5   Bidding behavior determines the outcome of an auction. The outcome of an auction means who gets what and who pays how much, etc. Different auction rules induce different bidding behavior on the part of bidders. A bidder's behavior under a given set of auction rules in turn is determined by his private information. The structure of private information held by bidders is

10   thus a key factor in evaluating alternative auction procedures (e.g., auction format, reserve prices, entry fees, timing and duration of the auction, quantity, participation rules, and information rules, etc.) from the point of view of a seller (or buyer) trying to sell (or procure) an item by auctioning. This fundamental element of an auction environment is not directly observable and

15   has to be estimated from observable and available data. The auction procedures can also be referred to as auction mechanisms. They include the characteristics of the auction.

        In accordance with one embodiment of the present invention, the

20   automatic decision support system 200 estimates the unknown or unobservable elements of the market structure of the auction by determining bidders' risk attitudes and private information. In the present embodiment, bidders' private information can be represented by a chart, or a graph. The private information can also be represented by a mathematical equation that

25   indicates the joint distribution of private information of the bidders (e.g., the probability distribution of bidders' willingness to pay, the probability distribution of the number of potential bidders, etc.). In particular, the

5   automatic decision support system 200 estimates the unknown elements of

the market structure by (1) expressing unobservable variables in the bidding

model in terms of the observable bid data, and (2) applying known statistical

density estimation techniques to the expression so as to obtain an estimation

of the unknown elements. In the embodiment shown in Figure 4, method 400

10   is used to determine bidders' risk attitude and private information. The

determined bidders' risk attitude and private information are used by the

automatic decision support system 200 to enable the user (either a seller or a

buyer) of the system 200 to factor the distribution of bidders' private

information into his/her decisions regarding the appropriate auction procedure

15   to conduct the auction.

With the estimated unknown elements of the market structure and

other user inputs (e.g., the auction design candidates, evaluation criterion),

the automatic decision support system 200 provides optimized auction design

20   candidates based on the evaluation criterion provided such that maximized

expected revenue or profit from the auction can be achieved. This means that

the automatic decision support system 200 can be used to configure

optimized auction parameters for a multiplicity of performance criteria. This

also means that the automatic decision support system 200 can be used to

25   configure auction parameters for the purpose of demand estimation. Thus,

even if seller/buyer chooses not to use auctions for selling or buying, properly

5   configured auctions can provide both rich sources of data and novel

estimation methodologies for demand estimation for the item.

       Continuing with Figure 2, automatic decision support system 200

includes a historical auction database 201, a bidding model database 202, a

10   structure extractor 203, a behavior predictor 204, and an optimizer 205. The

historical auction database 201 stores the historical auction data for

previously conducted auctions. The historical auction data includes auction

· characteristics and/or mechanisms of previous auctions. This means that the

historical auction data include the bid data and the auction characteristics

15   data of each of the stored previous auctions. The auction characteristics data

specify the auction procedure of the auction. In the present embodiment, the

auction characteristics data of an auction describe the reserve price of the

auctioned item, the auction format, the number of bidders, etc. of the

particular auction. The bid data of an auction describe the bidding behaviors

20   of bidders in the auction. The bid data is a record that typically contains the

auction identifier, number of bidders N, number of bids, transaction price,

winner, reserve price, auction format, item characteristics, bidder

characteristics. Both the bid data and the auction characteristics data are

extracted from the auction data of the previous or historical auctions for

25   various items. The historical auction database 201 can be implemented using

any known database technology.

5   The bidding model database 202 stores various bidding models. A

bidding model specifies a bidding behavior pattern. It is a function of auction

characteristics or procedure of the corresponding auction. It is also a function

of the market structure of the auction. For example, a Dutch auction bidding

model specifies bidding behavior in a Dutch format auction. An English

10   auction-bidding model specifies bidding behavior in an English format auction.

A utility-dependentauction-bidding model specifies bidding behavior in a

utility-dependentauction. The bidding model database 202 can be

implemented using any known database technology.

15   The structure extractor 203 estimates the unknown elements of the

market structure of the auction. The structure extractor 203 first receives the

user input of the item (and its characteristics) to be auctioned. The structure

extractor 203 then accesses the database 201 for the bid data and auction

characteristics data observed in previous or historical auctions of similar items

20   of the item. The structure extractor 203 is connected to the historical auction

database 201 and the bidding model database 202. The structure extractor

203 then produces a non-parametric structural estimate of the unobservable

latent structure of the environment of the auction. The structure extractor 203

uses auction theory and non-parametric statistical methods to extract an

25   estimate of the latent structure from the previously observed bids.

5   The bidding behavior predictor 204 predicts bidding behaviors of

bidders in the auction based on the user inputs of a set of auction decision

candidates and constraints. The bidding behavior predictor 204 receives the

estimated unknown elements of the market structure from the structure

extractor 203. In addition, the behavior predictor 204 receives the user inputs

10   of auction decision candidates and constraints.

The auction decision candidates are candidates for evaluation by the

system 200. For example, one auction decision candidate may be a Dutch

auction with a reserve price R_p between $100 and $300 for printer (i.e., the

15   item to be auctioned). Another auction decision candidate may be an English

auction with a reserve price R_p between $75 and $200 for printer.

The constraints specify limitations on the non-auction-format auction

parameters. For example, one of the constraints supplied to the behavior

20   predictor 204 can be that bidders must be invited for the Dutch auction of the

printer. Another constraint may be that bidders for the English auction need

not be invited to participate in the auction.

The behavior predictor 204 uses the received auction decision

25   candidates and the constraints to access the repository 202 in order to

receive the bidding model or models that match the auction decision

candidates. Then the behavior predictor 204 applies the estimated structure

5   elements to the bidding model or models to obtain the bidding behavior

prediction for each of the auction decision candidates.

The optimizer 205 is used to evaluate each auction decision candidate

provided by the user in accordance with evaluation criterion also provided by

10   the user of the system 200. The optimizer 205 employs the evaluation

criterion provided by the user to generate an evaluation of each of the auction

design candidates based on the estimated unknown elements of the market

structure and the predicted bidding behavior of bidders. Examples of the

evaluation criteria include expected profit, probability of sale, expected

15   efficiency, etc.

Figure 3 is a block diagram illustrating the process of obtaining the

relevant data in accordance with one embodiment of the present invention.

For a given auction item as shown in block 301 of Figure 3, multiple auctions

20   are run, illustrated in block 302 of Figure 3, and certain data is accumulated or

extracted as illustrated in block 303. The accumulated data 303 contains, but

may not be limited to, such information as the type of auction, auction

characteristics or rules, the item being auctioned and its characteristics, the

number of submitted bids, the number of bidders, and the characteristics of

25   each bidder including the bid price. For a given item, multiple auctions are

held and multiple sets of data are accumulated. These data sets are all stored

in the auction database or historical auction data database, illustrated in block

5 304 of Figure 3 and block 201 of Figure 2, for future use in jointly estimating

bidders' private information and risk attitudes.

Figure 4 is a process block diagram of the steps in a process 400 for

obtaining the estimates of bidders' risk attitudes and private information in

10 accordance with one embodiment of the present invention. In the present

embodiment, aspects of process 400 are implemented using a computer

system 190 as illustrated in Figure 1. However it is appreciated that process

400 can be implemented on a different computer system. Although specific

steps are disclosed in process 400, such steps are exemplary. That is, the

15 present invention is well suited to performing various other steps or variations

of the steps recited in Figure 4. Within the present embodiment, it should be

appreciated that the steps of process 400 may be performed by software or

hardware or by any combination of software and hardware.

20 As shown by step 401, auction data from previously conducted

auctions is analyzed. In the present embodiment, the characteristics of the

item of interest are input. Auction data from previously conducted auctions for

the same or similar items is analyzed. Auction data can include auction

format, auction item, time of auction, number of bidders, number of submitted

25 bids, characteristics of each bidder and price bid. If the item in step 401 has

previously been auctioned, the relevant information from the auction is

factored into the database for estimating the bidders' private information.

In one embodiment of step 401, the analyzed data from previously

30 conducted auctions is accumulated into each of two sets as a function of the

auction format. Data in the first set includes utility-independent (or Vickrey)

5   auction data. In these auctions the highest bidder wins but pays the second

highest price. Therefore the utility-independent auction format factors out the

bidders' risk attitude, known as the utility function, $U()$. This is an optimal

bidding strategy as it is only dependent upon what the bidder is willing to pay,

or the demand function, $1-F()$. where $F()$ is the joint distribution of bidders'

10   private information.

       Referring to steps 402 and 403, if there is insufficient auction data from

the previously conducted utility-independent for determining bidders' private

information, additional utility-independent auctions are conducted, as shown

15   in step 403, until sufficient information is obtained.

       In step 404 bidders' private information is determined. In the present

embodiment, private information is represented by a demand function, $1-F(v_i)$,

where v_i $(i = 1, ...n)$ denotes the bidder i's private information. This demand

20   function is typically interpreted as bidder i's willingness to pay for the item. In

one embodiment, determination of private information is obtained using a

non-parametric estimation of the joint distribution of private information, $F(v_i,$

$... v_n)$ of the bidders.

25   Figure 5 illustrates an exemplary graph of a demand function, $1-F()$ as

a function of Price, P. This data set is used to non-parametrically estimate the

joint distribution of private information, $F(v_1, ... v_n)$, of the bidders.

       Referring to steps 405 and 406, if there is insufficient data from

30   previously conducted utility-dependent auctionsfor determining risk attitudes,

additional utility-dependent auctionsare conducted. These additional auctions

5   are conducted, as shown in step 406, until sufficient information is obtained.

In the present embodiment first price sealed bid auctions are representative of

the utility function, $U()$, or the bidders' attitude toward risk.

As shown by step 407, risk attitude is determined. In the present

10   embodiment risk attitude is represented by a utility of wealth function, $U(w)$

that is representative of the bidders' attitudes toward risk. If a bidder with

private valuation, v_i, and current wealth, w, wins the item at a price, b, his

utility of winning the auction is $U(w + v_i - b)$, and his utility of not winning is

$U(w)$. A concave function $U()$ indicates risk aversion, whereas a linear utility

15   of wealth function characterizes risk neutrality.

Continuing with step 407 of Figure 4, in the present embodiment, the

joint distribution function, $F()$, that represents private information, is used in

20   the structural analysis of both auction data from previously conducted

auctions and auction data from step 406 to non-parametrically estimate the

unknown utility of wealth function, $U()$.

A report is then generated that indicates $F()$ and $U()$ from steps 404

25   and 407. In the present embodiment, the report is in tabular form.

Alternatively, the report is in graphical form or in the form of a mathematical

function.

In one embodiment of the present invention step 407 of Figure 4 is

30   performed according to the following example. In the present example,

several copies of the same item are to be sold (e.g., several identical

5   printers). Several auctions are analyzed using the second-price sealed bid

format. Under this format, each bidder is expected to bid his value, i.e., he

does not "shade" his bid. Thus, the joint distribution of the bidders' values can

be estimated by using standard statistical density estimation techniques

applied to the bid data directly. Several auctions are then analyzed (and/or

10   new auctions are conducted) using the sealed-bid first-price format. Under

such a format, the bid submitted by a bidder depends on both his value and

his risk attitude. Assume that there are k symmetric bidders in each auction.

Let their common utility function be $U()$. Then the value v and bid b of a

bidder is related by the following equation:

15   (1) $$v = b + \lambda^{-1}\left(\frac{G(b)}{(k-1)g(b)}\right),$$

where $G()$ and $g()$ are the distribution function and density function,

respectively, of b, and λ^{-1} is the inverse of the function $\lambda = U/U'$. The problem

we face is estimating $U()$, or equivalently, $\lambda()$. The following "quantile-

matching" method can then be used for estimating $U()$, or equivalently, $\lambda()$,

20   wherein $v_0, v_{1/100}, v_{2/100}, \ldots, v_{99/100}, v_1$ are quantities of v satisfying the

relationship $F(v_{j/100}) = j/100, j = 0, 1, \ldots, 100$, where F is the (marginal)

distribution of v estimated from the first stage of the experiment.

In the present embodiment $b_0, b_{1/100}, b_{2/100}, \ldots, b_{99/100}, b_1$ are similarly

25   defined quantiles of b. Next, we use the fact that the corresponding quantiles

of b and v must satisfy equation (1), giving the equation:

30   (2) $$v_{j/100} + b_{j/100} + \lambda^{-1}\left(\frac{G(b_{j/100})}{(k-1)g(b_{j/100})}\right).$$

5   In equation (2), $G(b_{j/100}) = j/100$ by definition of $b_{j/100}$, and $g(b_{j/100})$ can be estimated using standard density estimation techniques applied to the bid data. Hence, equation (2) provides us with an estimate of $\lambda^{-1}()$ and hence of $\lambda()$, on a discrete set of points. From this, we derive an estimate of $U()$ by

10   solving the differential equation $\lambda = U/U'$, which leads to the equation:

(3) $$U(w) = \exp\left(\int_0^w (1/\lambda(u))du\right).$$

Thus, the present invention allows a decision-maker to estimate the unobservable risk attitudes and private information of bidders without

15   resorting necessarily to ad hoc a priori assumptions on the functional forms of these unknowns. Thereby, the present invention enables a seller or buyer conducting an auction for selling or procuring an item(s), to make decisions regarding the appropriate auction procedure to conduct that accurately reflects the bidders' attitude toward risk and the distribution of bidders' private

20   information. Thus, the present invention allows for a more accurate formulation of decision problems faced by bidders and auction houses and, therefore, provides a more reliable identification of optimal decisions.

The preferred embodiment of the present invention, a method and

25   apparatus for determining private information and risk attitudes, is thus described. While the present invention has been described in particular embodiments, it should be appreciated that the present invention should not be construed as limited by such embodiments, but rather construed according to the below claims.